FIG. 1

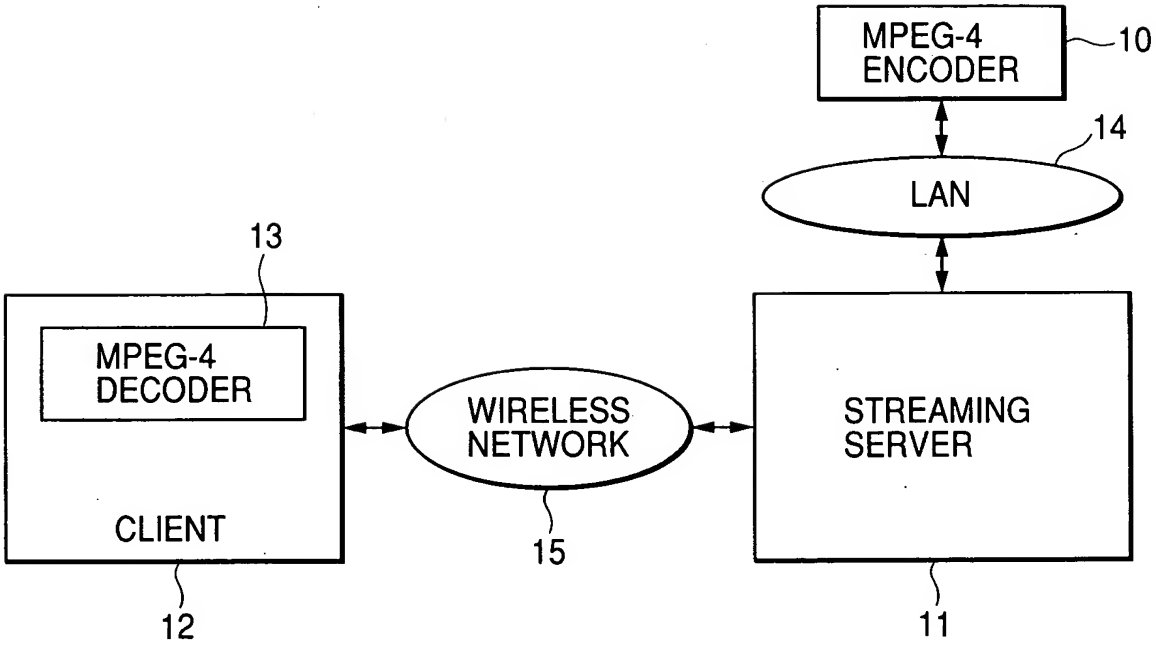

MPEG-4
ENCODER
10
14
LAN
13
MPEG-4
DECODER
WIRELESS
NETWORK
STREAMING
SERVER
CLIENT
15
12
11

FIG. 2

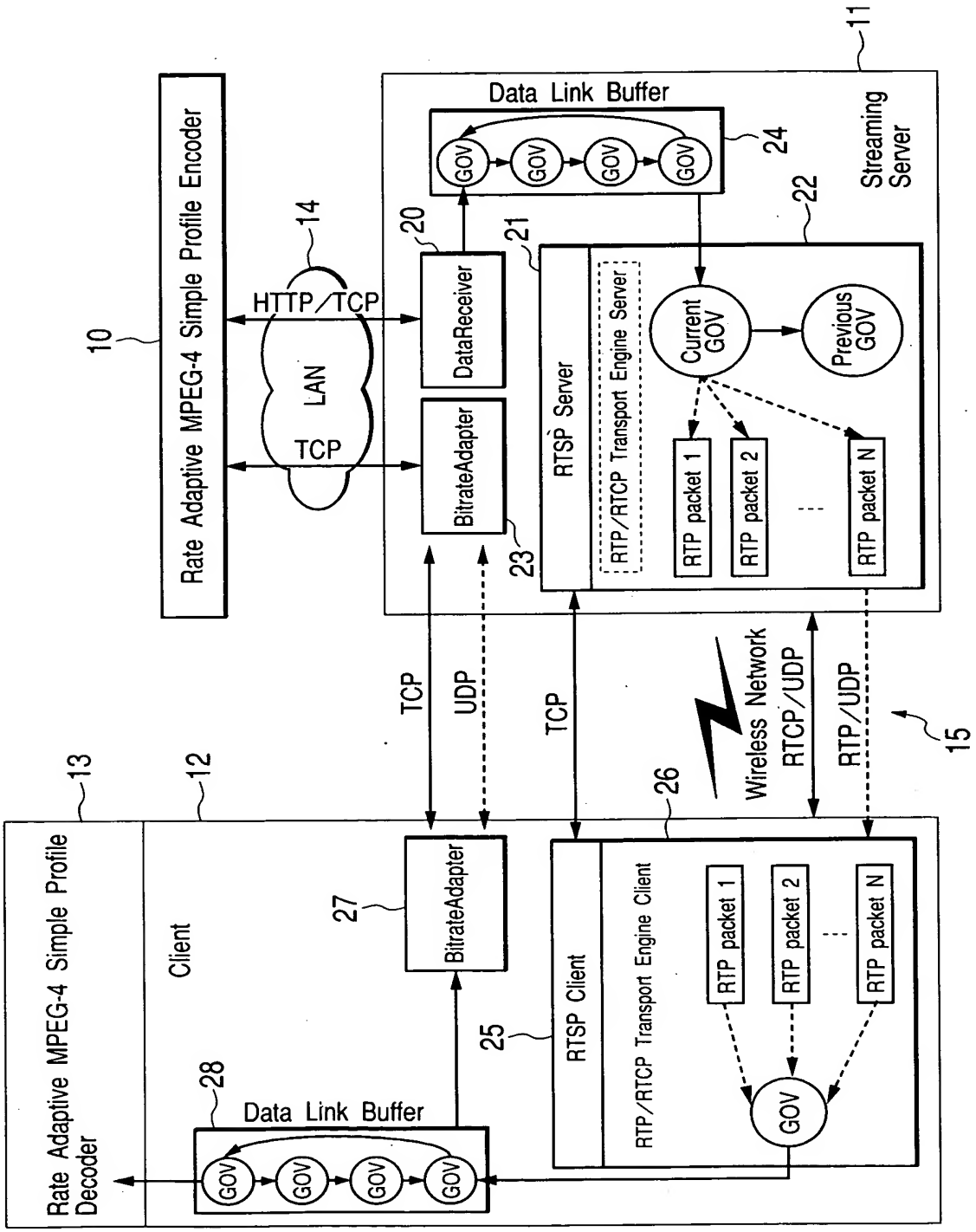

Rate Adaptive MPEG-4 Simple Profile Encoder
10
HTTP/TCP
LAN
TCP
14
Data Link Buffer
GOV
24
Streaming Server
11
22
20
DataReceiver
21
BitrateAdapter
23
RTSP Server
RTP/RTCP Transport Engine Server
Current GOV
Previous GOV
RTP packet 1
RTP packet 2
RTP packet N
TCP
UDP
TCP
Wireless Network
RTCP/UDP
RTP/UDP
15
13
12
26
Rate Adaptive MPEG-4 Simple Profile Decoder
Client
27
BitrateAdapter
25
RTSP Client
RTP/RTCP Transport Engine Client
RTP packet 1
RTP packet 2
RTP packet N
GOV
28
Data Link Buffer
GOV

FIG. 3

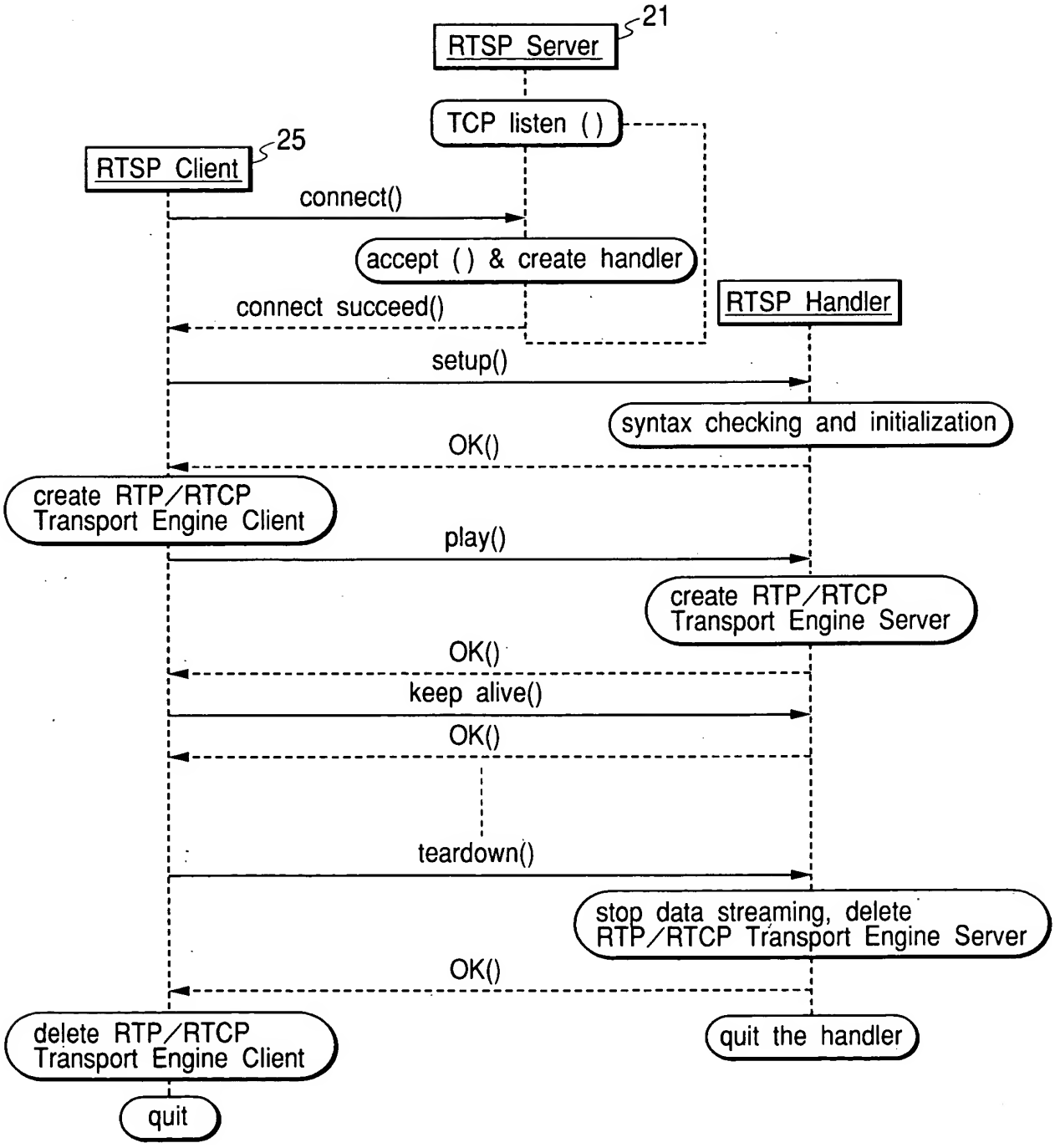

RTSP Server
21
TCP listen ( )
RTSP Client
25
connect()
accept ( ) & create handler
RTSP Handler
connect succeed()
setup()
syntax checking and initialization
OK()
create RTP/RTCP
Transport Engine Client
play()
create RTP/RTCP
Transport Engine Server
OK()
keep alive()
OK()
teardown()
stop data streaming, delete
RTP/RTCP Transport Engine Server
OK()
delete RTP/RTCP
Transport Engine Client
quit the handler
quit

FIG. 4

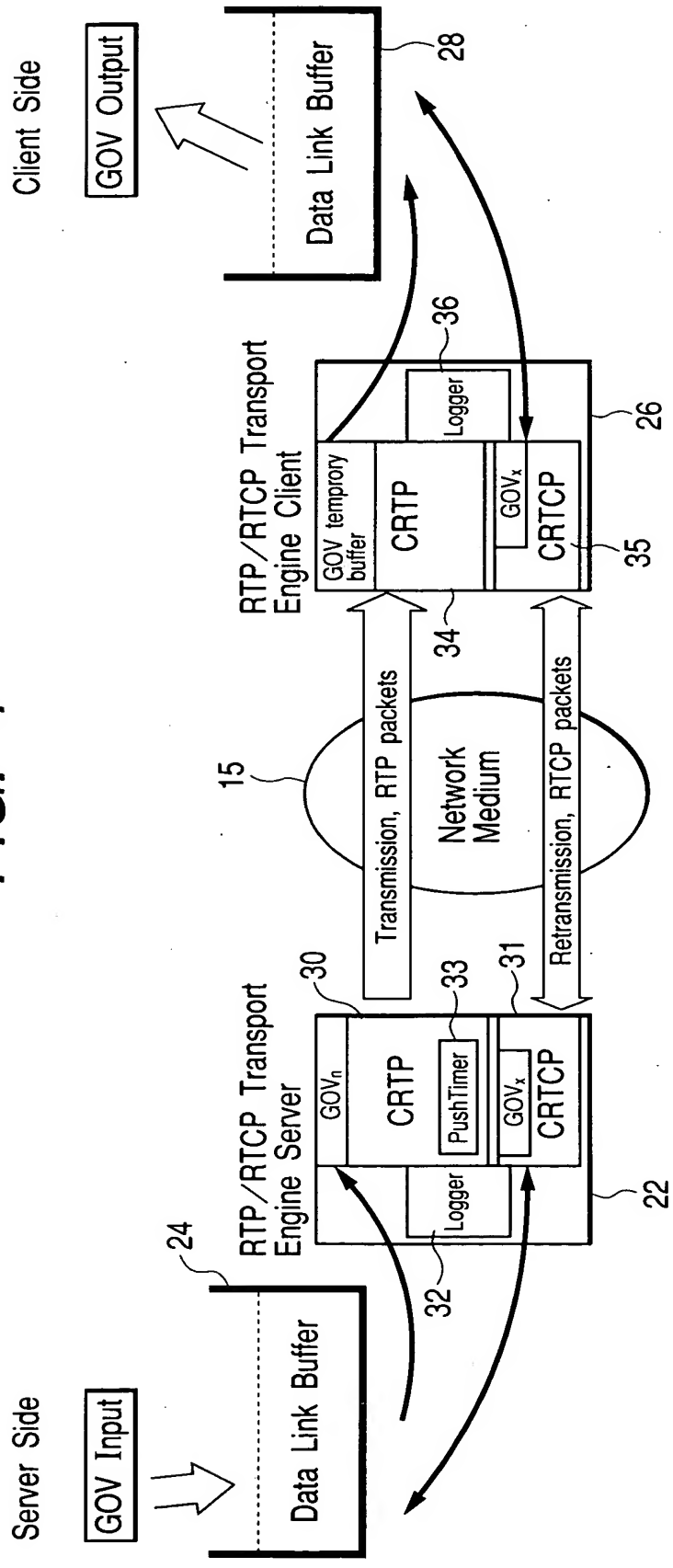

Server Side
GOV Input
Data Link Buffer
24
RTP/RTCP Transport Engine Server
GOV$_n$
CRTP
PushTimer
GOV$_x$
CRTCP
Logger
32
30
33
31
22
Transmission, RTP packets
Retransmission, RTCP packets
15
Network Medium
34
RTP/RTCP Transport Engine Client
GOV temprory buffer
CRTP
GOV$_x$
CRTCP
Logger
36
35
26
Client Side
GOV Output
Data Link Buffer
28

FIG. 5

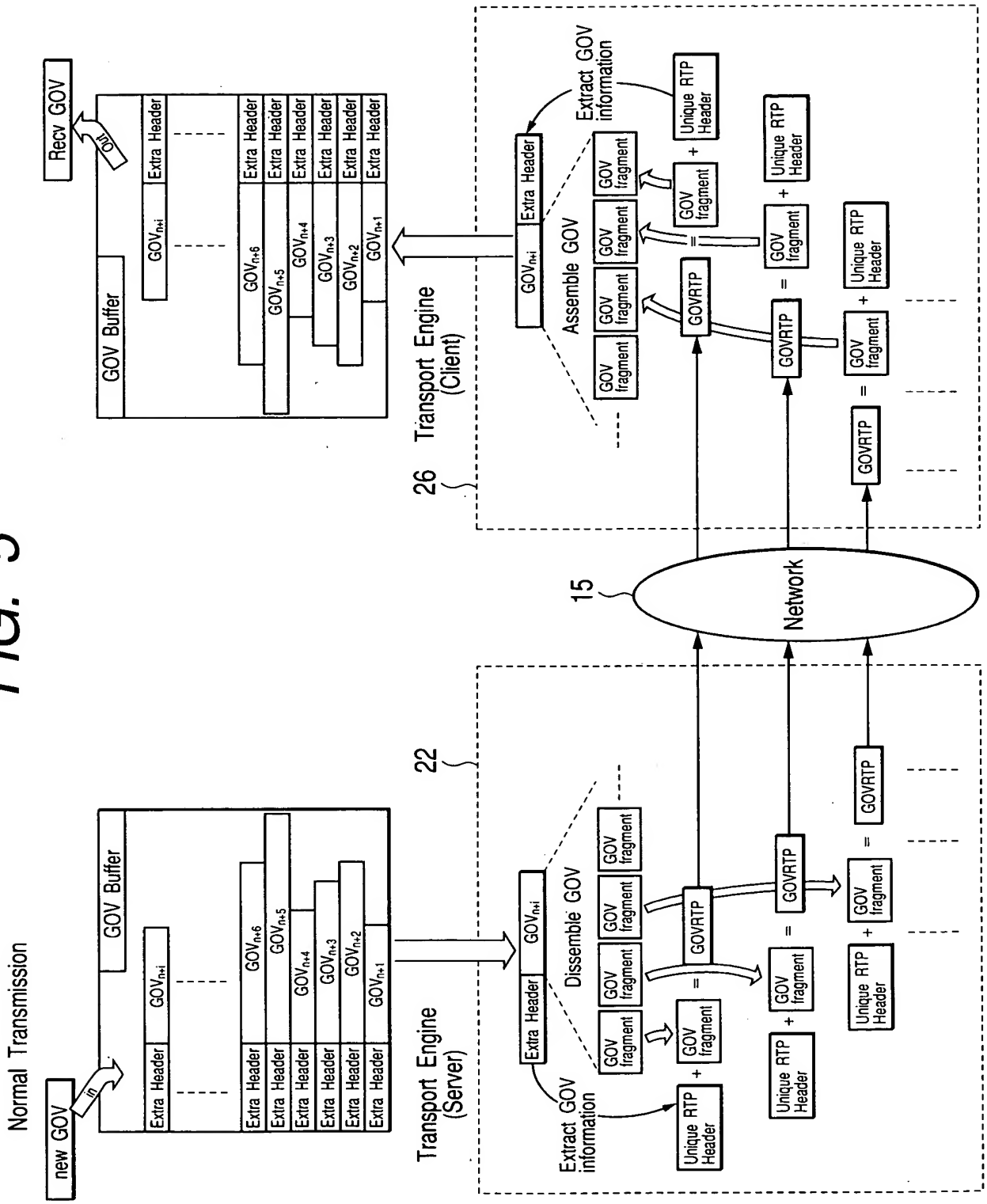

Normal Transmission
new GOV
In
GOV Buffer
Extra Header
GOV$_{n+i}$
GOV$_{n+6}$
GOV$_{n+5}$
GOV$_{n+4}$
GOV$_{n+3}$
GOV$_{n+2}$
GOV$_{n+1}$
Transport Engine (Server)
22
Dissemble GOV
Extract GOV information
Unique RTP Header
GOV fragment
GOVRTP
15
Network
26
Transport Engine (Client)
Assemble GOV
Extract GOV information
Out
Recv GOV

FIG. 6

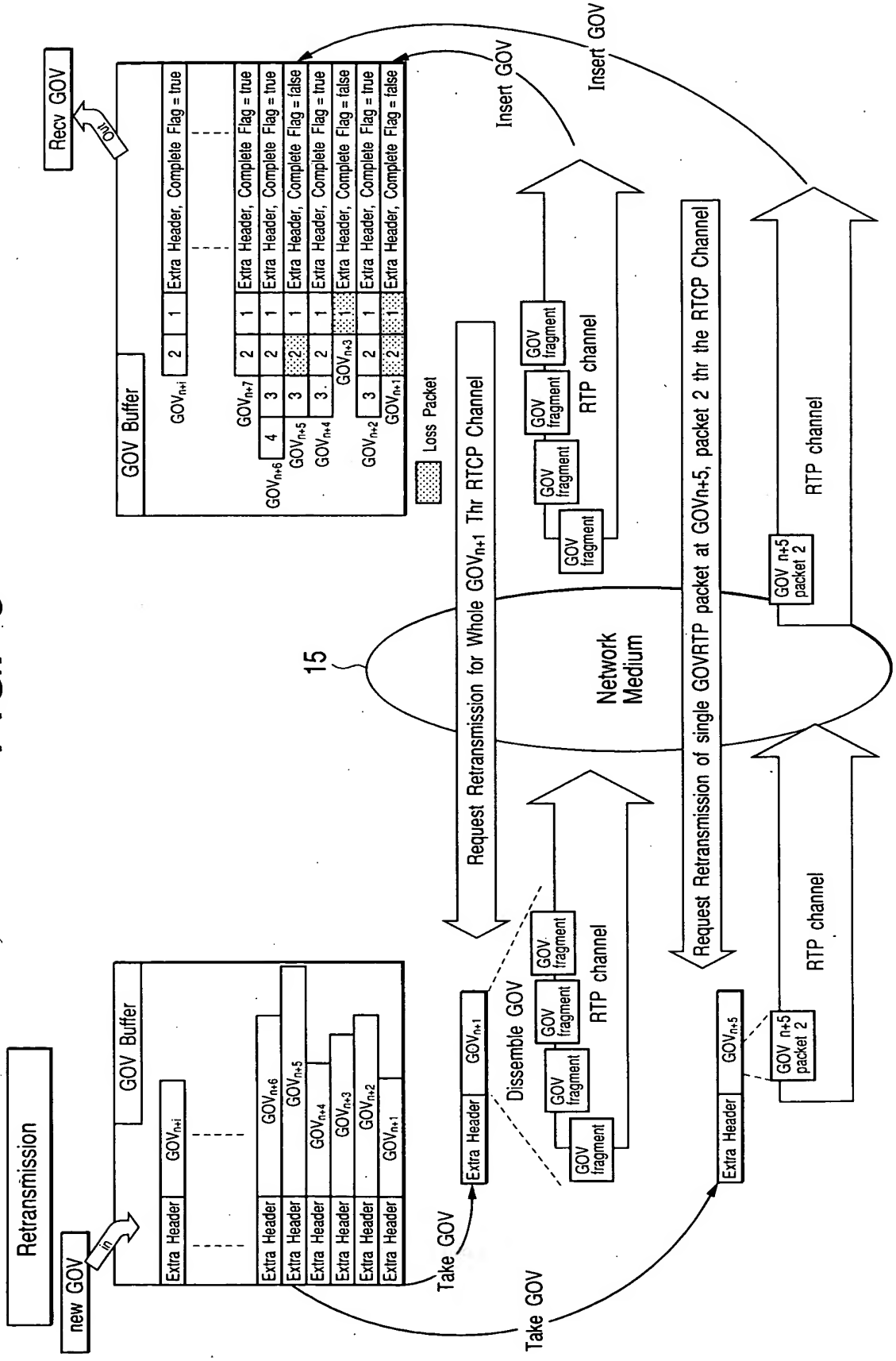

Retransmission
new GOV
in
GOV Buffer
Extra Header
GOV$_{n+i}$
GOV$_{n+6}$
GOV$_{n+5}$
GOV$_{n+4}$
GOV$_{n+3}$
GOV$_{n+2}$
GOV$_{n+1}$
Take GOV
Extra Header
GOV$_{n+1}$
Dissemble GOV
GOV fragment
RTP channel
Request Retransmission for Whole GOV$_{n+1}$ Thr RTCP Channel
15
Network Medium
Request Retransmission of single GOVRTP packet at GOVn+5, packet 2 thr the RTCP Channel
GOV n+5 packet 2
RTP channel
Insert GOV
Take GOV
Recv GOV
out
GOV Buffer
Extra Header, Complete Flag = true
Extra Header, Complete Flag = false
Loss Packet
Insert GOV

FIG. 7

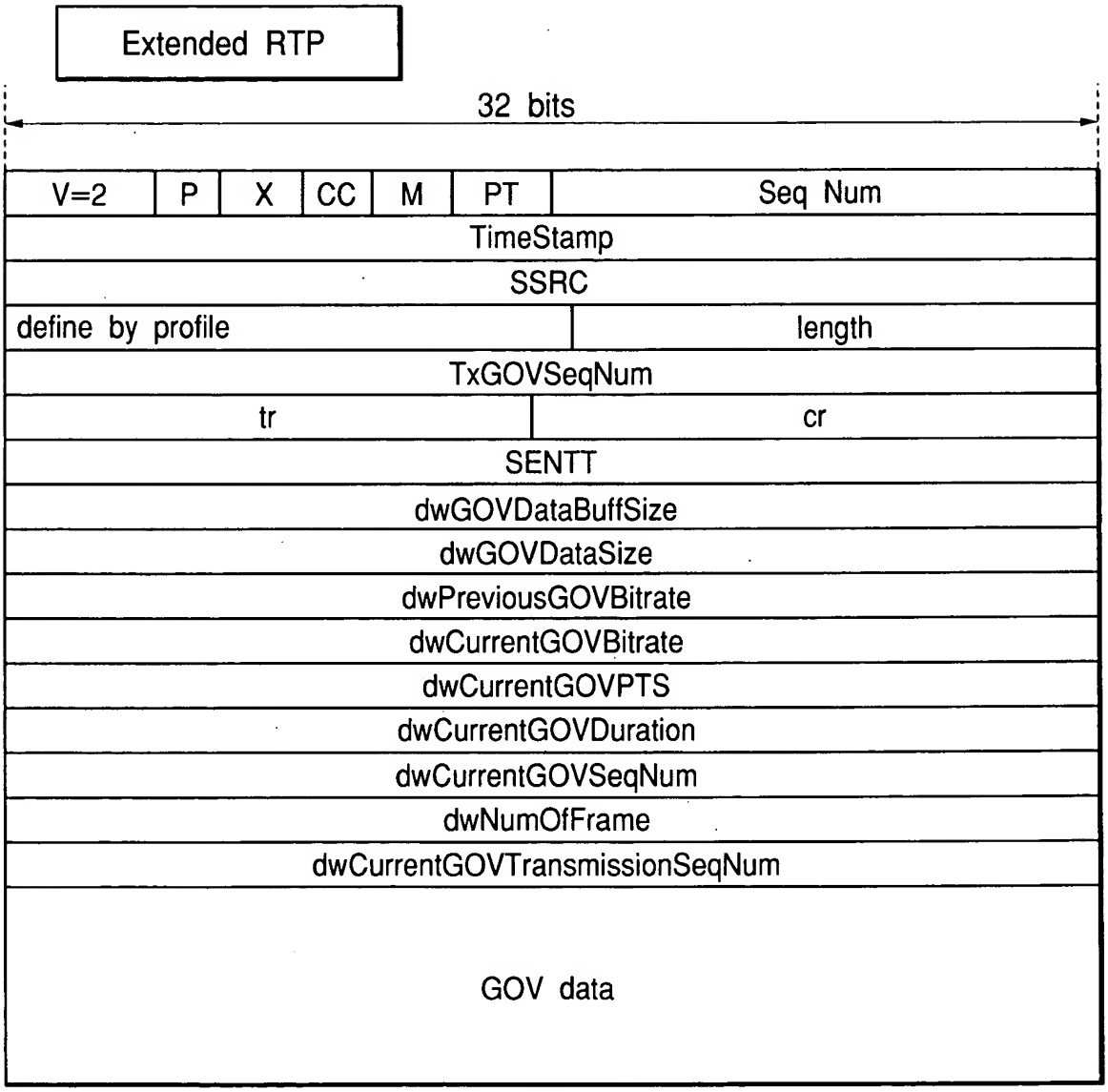

Extended RTP
32 bits
V=2
P
X
CC
M
PT
Seq Num
TimeStamp
SSRC
define by profile
length
TxGOVSeqNum
tr
cr
SENTT
dwGOVDataBuffSize
dwGOVDataSize
dwPreviousGOVBitrate
dwCurrentGOVBitrate
dwCurrentGOVPTS
dwCurrentGOVDuration
dwCurrentGOVSeqNum
dwNumOfFrame
dwCurrentGOVTransmissionSeqNum
GOV data

FIG. 8

Fields in The Extended RTP Packet

Field	Size (bit)	Function
V=2	2	As in RFC1889
P	1	As in RFC1889
X	1	As in RFC1889
CC	4	As in RFC1889
M	1	As in RFC1889
PT	7	As in RFC1889
Seq Num	8	As in RFC1889
Time Stamp	32	As in RFC1889
SSRC	32	As in RFC1889
Profile	16	Extended Profile
Length	16	Extended header length
TxGOVSeqNum	32	GOV Sequence Number used in Transmission
Tr	16	Total RTP packet for this GOV
Cr	16	Current RTP number for this GOV
SENTT	32	Server Estimated Next Transmission Time
dwGOVDataBuffSize	32	The byte's number of the GOV data buffer
dwGOVDataSize	32	The actual byte's number of GOV data
dwPreviousGOVBitrate	32	The bitrate of last GOV
dwCurrentGOVBitrate	32	The bitrate of current GOV
dwCurrentGOVPTS	32	The starting PTS of current GOV
dwCurrentGOVDuration	32	The duration of current GOV
dwCurrentGOVSeqNum	32	The unique sequence number of current GOV
DwNumOfFrame	32	The frame number of current GOV
dwCurrentGOVTransmissionSeqNum	32	The transmission sequence number of current GOV

FIG. 9

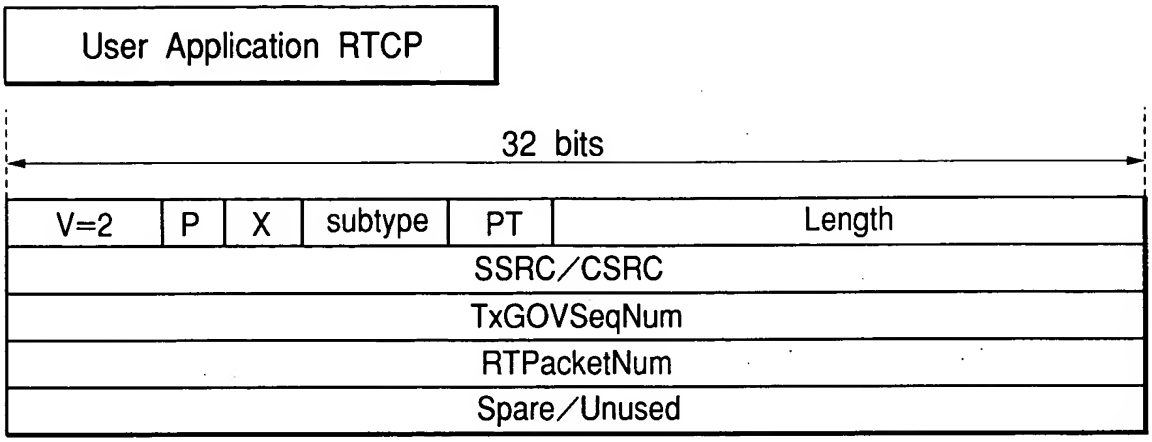


FIG. 10

Fields in The User Application RTCP Packet

Field	Size (bit)	Function
V=2	2	As in RFC1889
P	1	As in RFC1889
X	1	As in RFC1889
Subtype	5	As in RFC1889
PT	8	As in RFC1889
Length	16	As in RFC1889
TxGOVSeqNum	32	Requested GOV Sequence Number to be retransmitted
RTPPacketNum	32	Requested RTP packet number to be retransmitted, if equal to -1, retransmit the whole GOV
Spare/Unused	32	Reserved for future used

FIG. 11

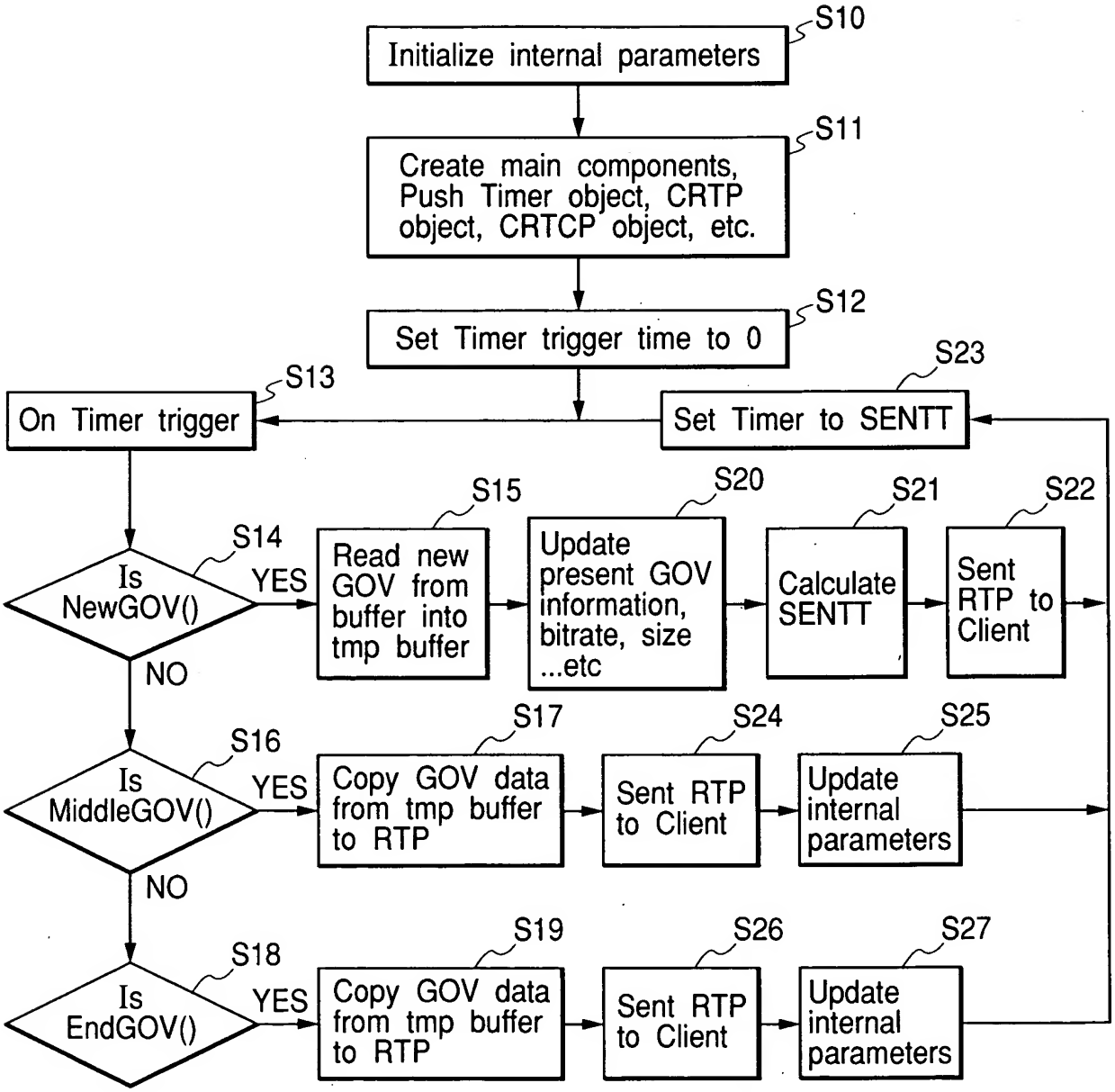

S10
Initialize internal parameters
S11
Create main components, Push Timer object, CRTP object, CRTCP object, etc.
S12
Set Timer trigger time to 0
S23
Set Timer to SENTT
S13
On Timer trigger
S14
Is NewGOV()
YES
NO
S15
Read new GOV from buffer into tmp buffer
S20
Update present GOV information, bitrate, size ...etc
S21
Calculate SENTT
S22
Sent RTP to Client
S16
Is MiddleGOV()
YES
NO
S17
Copy GOV data from tmp buffer to RTP
S24
Sent RTP to Client
S25
Update internal parameters
S18
Is EndGOV()
YES
S19
Copy GOV data from tmp buffer to RTP
S26
Sent RTP to Client
S27
Update internal parameters

FIG. 12

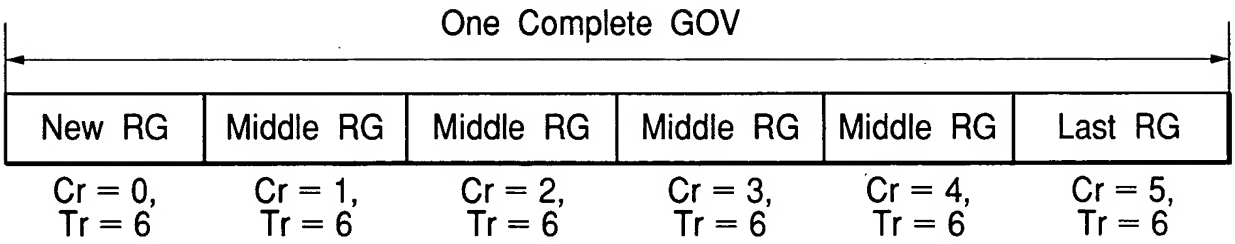

One Complete GOV
New RG
Middle RG
Middle RG
Middle RG
Middle RG
Last RG
Cr = 0, Tr = 6
Cr = 1, Tr = 6
Cr = 2, Tr = 6
Cr = 3, Tr = 6
Cr = 4, Tr = 6
Cr = 5, Tr = 6

FIG. 13

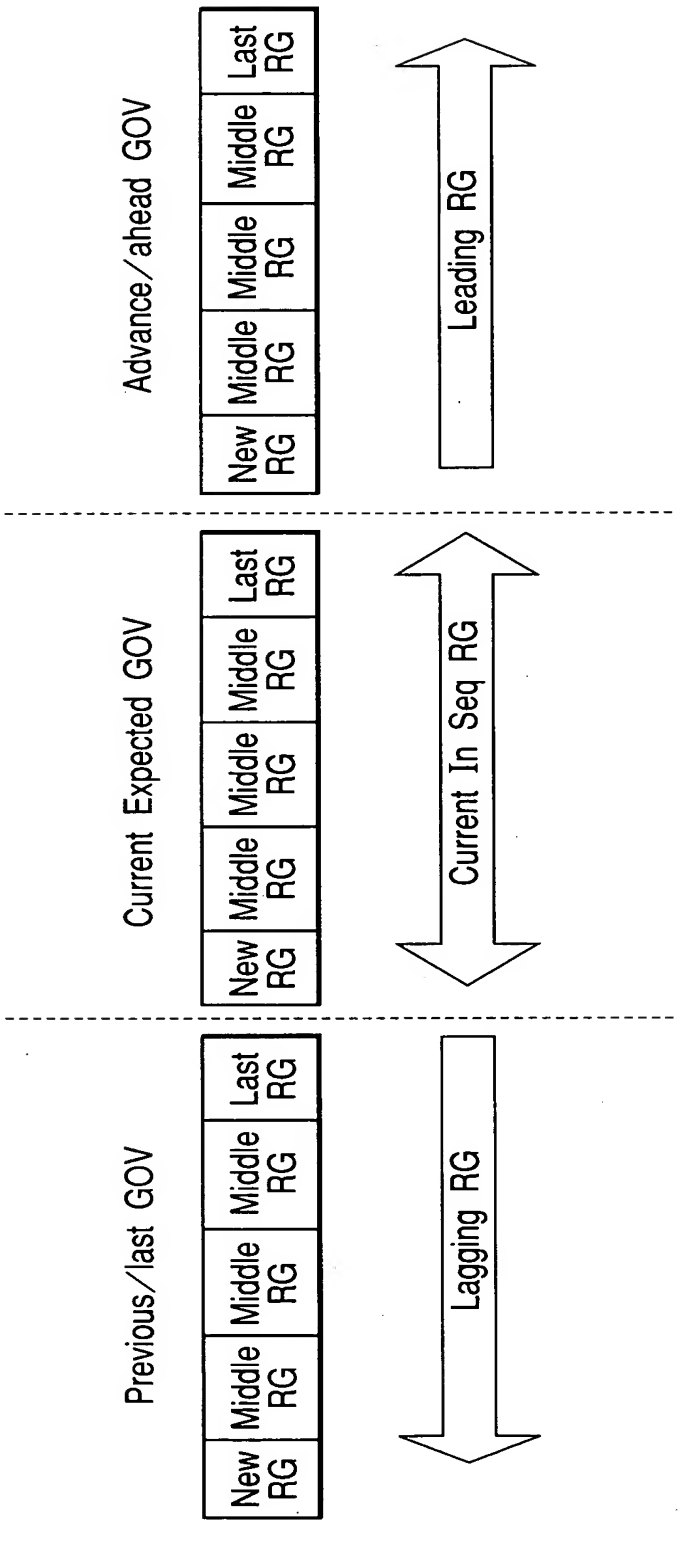

Previous/last GOV
New RG
Middle RG
Middle RG
Middle RG
Last RG
Current Expected GOV
New RG
Middle RG
Middle RG
Middle RG
Middle RG
Last RG
Advance/ahead GOV
New RG
Middle RG
Middle RG
Middle RG
Middle RG
Last RG
Lagging RG
Current In Seq RG
Leading RG

FIG. 14

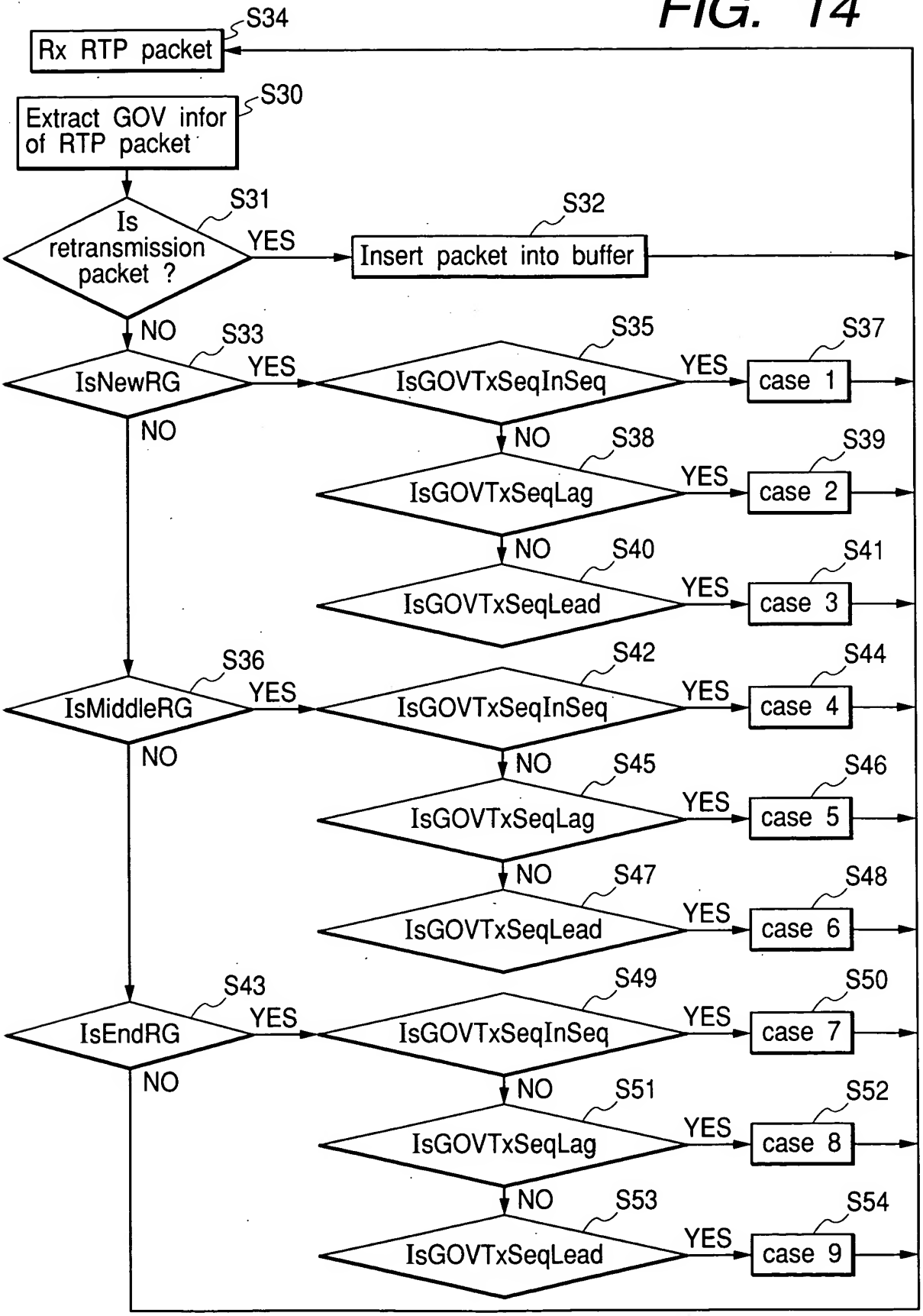

S34
Rx RTP packet
S30
Extract GOV infor of RTP packet
S31
Is retransmission packet ?
YES
S32
Insert packet into buffer
NO
S33
IsNewRG
YES
S35
IsGOVTxSeqInSeq
YES
S37
case 1
NO
NO
S38
IsGOVTxSeqLag
YES
S39
case 2
NO
S40
IsGOVTxSeqLead
YES
S41
case 3
S36
IsMiddleRG
YES
S42
IsGOVTxSeqInSeq
YES
S44
case 4
NO
NO
S45
IsGOVTxSeqLag
YES
S46
case 5
NO
S47
IsGOVTxSeqLead
YES
S48
case 6
S43
IsEndRG
YES
S49
IsGOVTxSeqInSeq
YES
S50
case 7
NO
NO
S51
IsGOVTxSeqLag
YES
S52
case 8
NO
S53
IsGOVTxSeqLead
YES
S54
case 9

FIG. 15

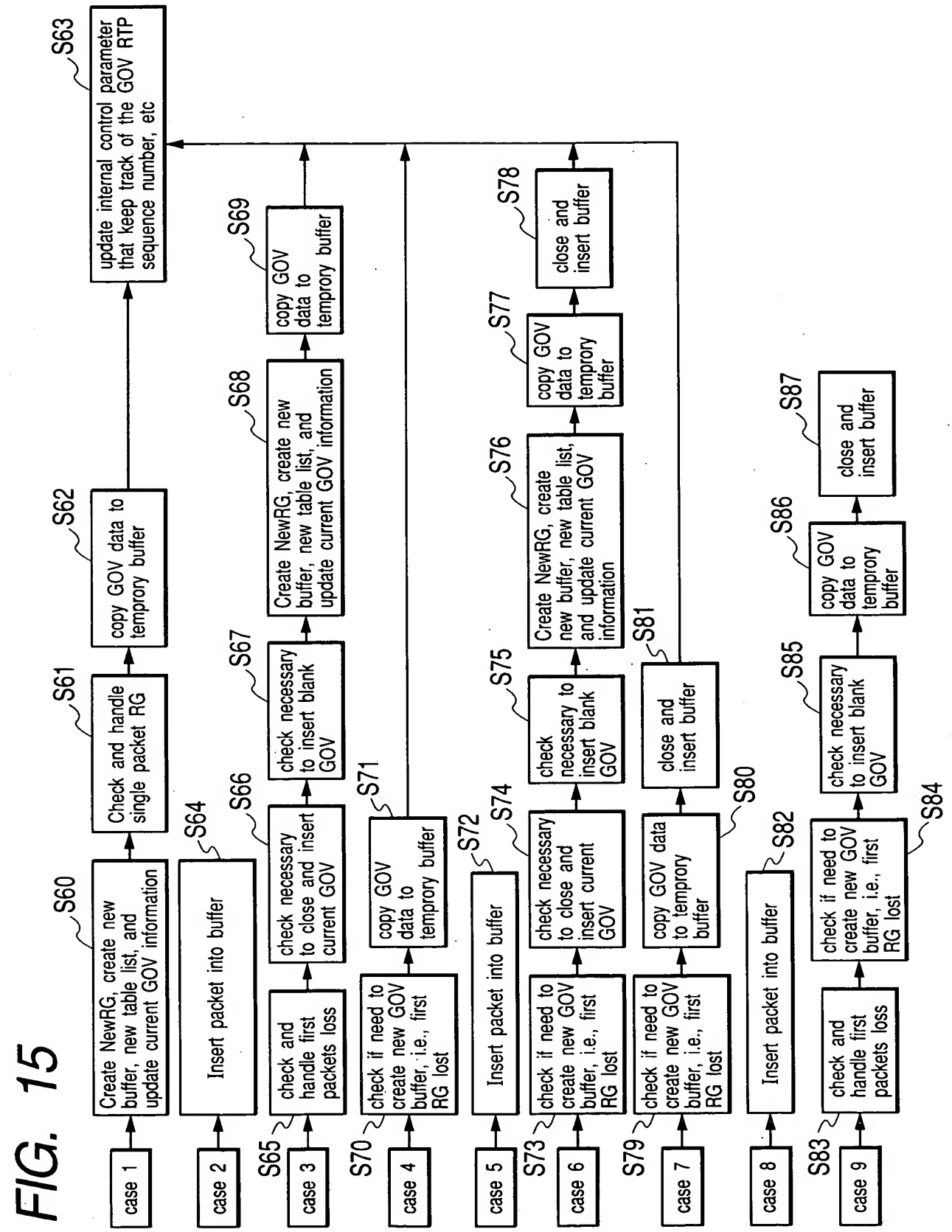

case 1
Create NewRG, create new buffer, new table list, and update current GOV information
S60
Check and handle single packet RG
S61
copy GOV data to temprory buffer
S62
update internal control parameter that keep track of the GOV RTP sequence number, etc
S63
case 2
Insert packet into buffer
S64
case 3
check and handle first packets loss
S65
check necessary to close and insert current GOV
S66
check necessary to insert blank GOV
S67
Create NewRG, create new buffer, new table list, and update current GOV information
S68
copy GOV data to temprory buffer
S69
case 4
check if need to create new GOV buffer, i.e., first RG lost
S70
copy GOV data to temprory buffer
S71
case 5
Insert packet into buffer
S72
case 6
check if need to create new GOV buffer, i.e., first RG lost
S73
check necessary to close and insert current GOV
S74
check necessary to insert blank GOV
S75
Create NewRG, create new buffer, new table list, and update current GOV information
S76
copy GOV data to temprory buffer
S77
close and insert buffer
S78
case 7
check if need to create new GOV buffer, i.e., first RG lost
S79
copy GOV data to temprory buffer
S80
close and insert buffer
S81
case 8
Insert packet into buffer
S82
case 9
check and handle first packets loss
S83
check if need to create new GOV buffer, i.e., first RG lost
S84
check necessary to insert blank GOV
S85
copy GOV data to temprory buffer
S86
close and insert buffer
S87

FIG. 16

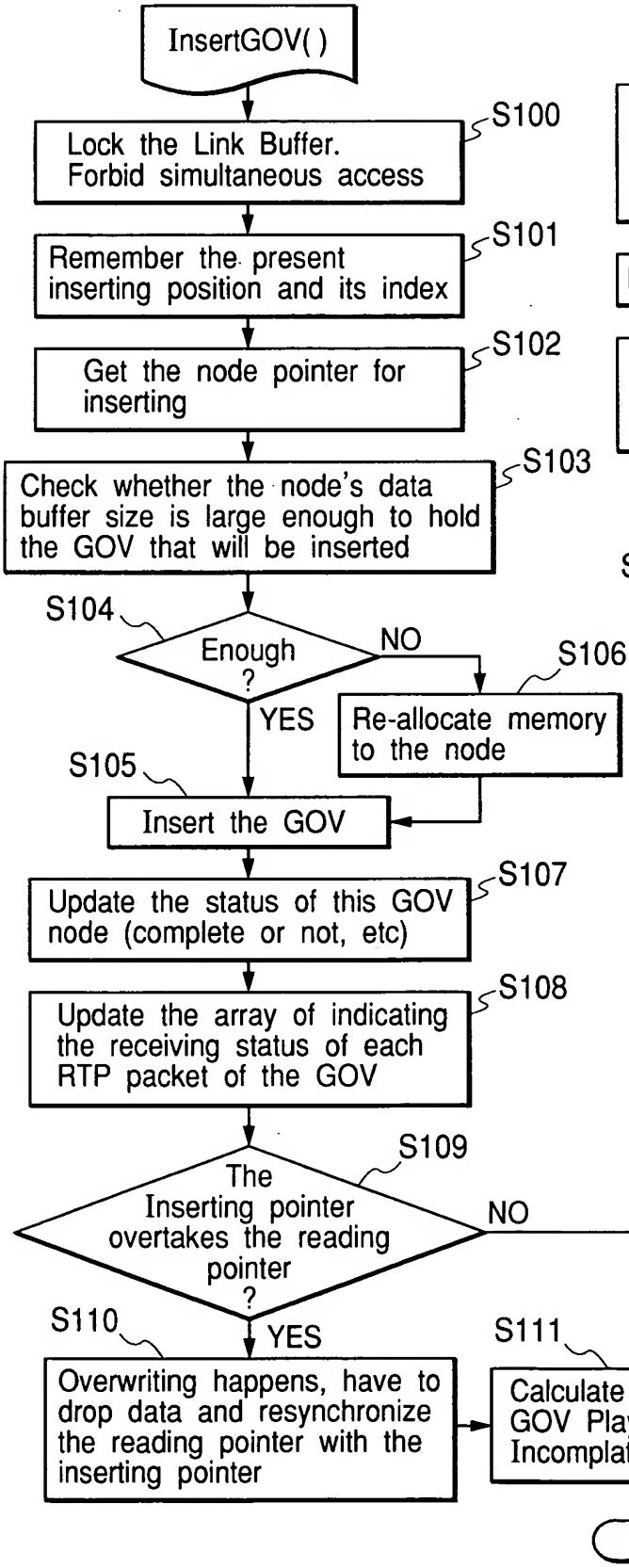

InsertGOV( )
Lock the Link Buffer. Forbid simultaneous access
S100
Remember the present inserting position and its index
S101
Get the node pointer for inserting
S102
Check whether the node's data buffer size is large enough to hold the GOV that will be inserted
S103
S104
Enough ?
NO
S106
Re-allocate memory to the node
YES
S105
Insert the GOV
Update the status of this GOV node (complete or not, etc)
S107
Update the array of indicating the receiving status of each RTP packet of the GOV
S108
S109
The Inserting pointer overtakes the reading pointer ?
NO
S110
YES
Overwriting happens, have to drop data and resynchronize the reading pointer with the inserting pointer
S111
Calculate the Remaining GOV Playback Time and the Incomplate GOV Number
END

FIG. 17

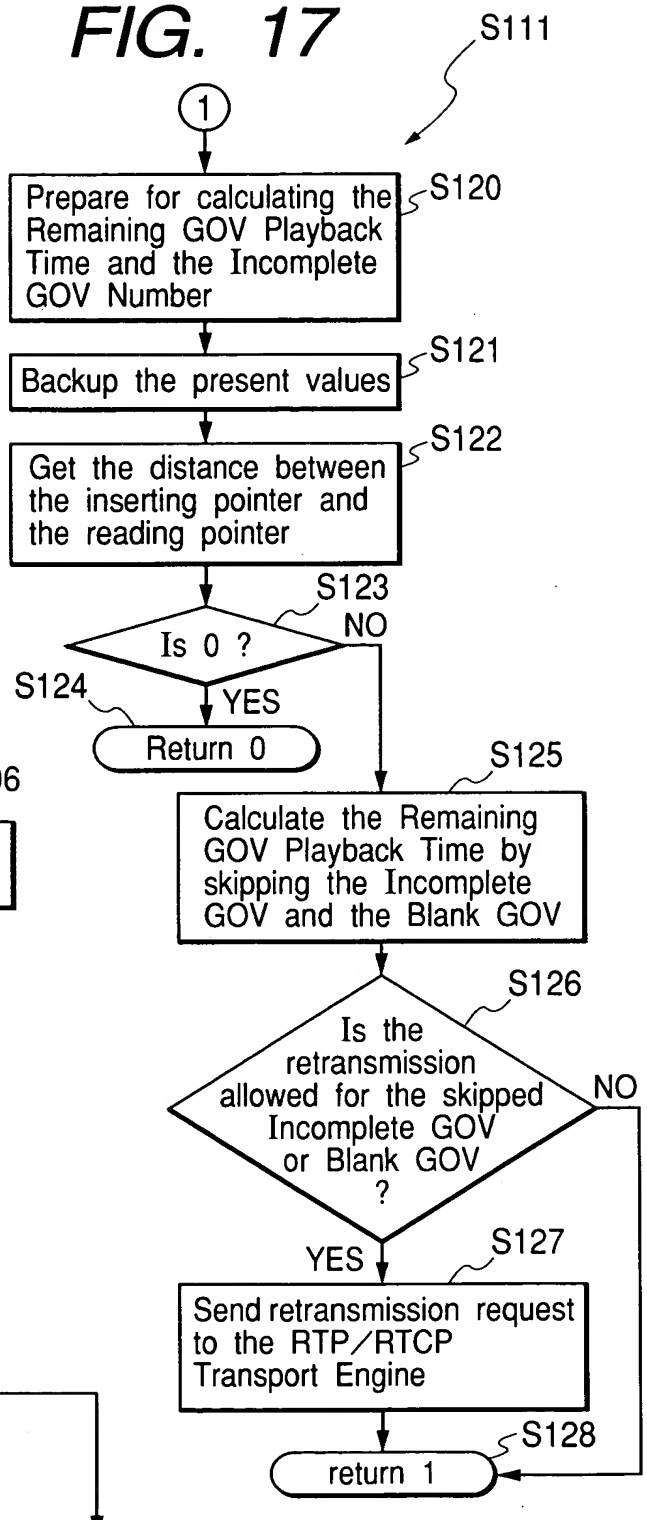

S111
1
Prepare for calculating the Remaining GOV Playback Time and the Incomplete GOV Number
S120
Backup the present values
S121
Get the distance between the inserting pointer and the reading pointer
S122
S123
Is 0 ?
NO
S124
YES
Return 0
S125
Calculate the Remaining GOV Playback Time by skipping the Incomplete GOV and the Blank GOV
S126
Is the retransmission allowed for the skipped Incomplete GOV or Blank GOV ?
NO
YES
S127
Send retransmission request to the RTP/RTCP Transport Engine
S128
return 1

FIG. 18

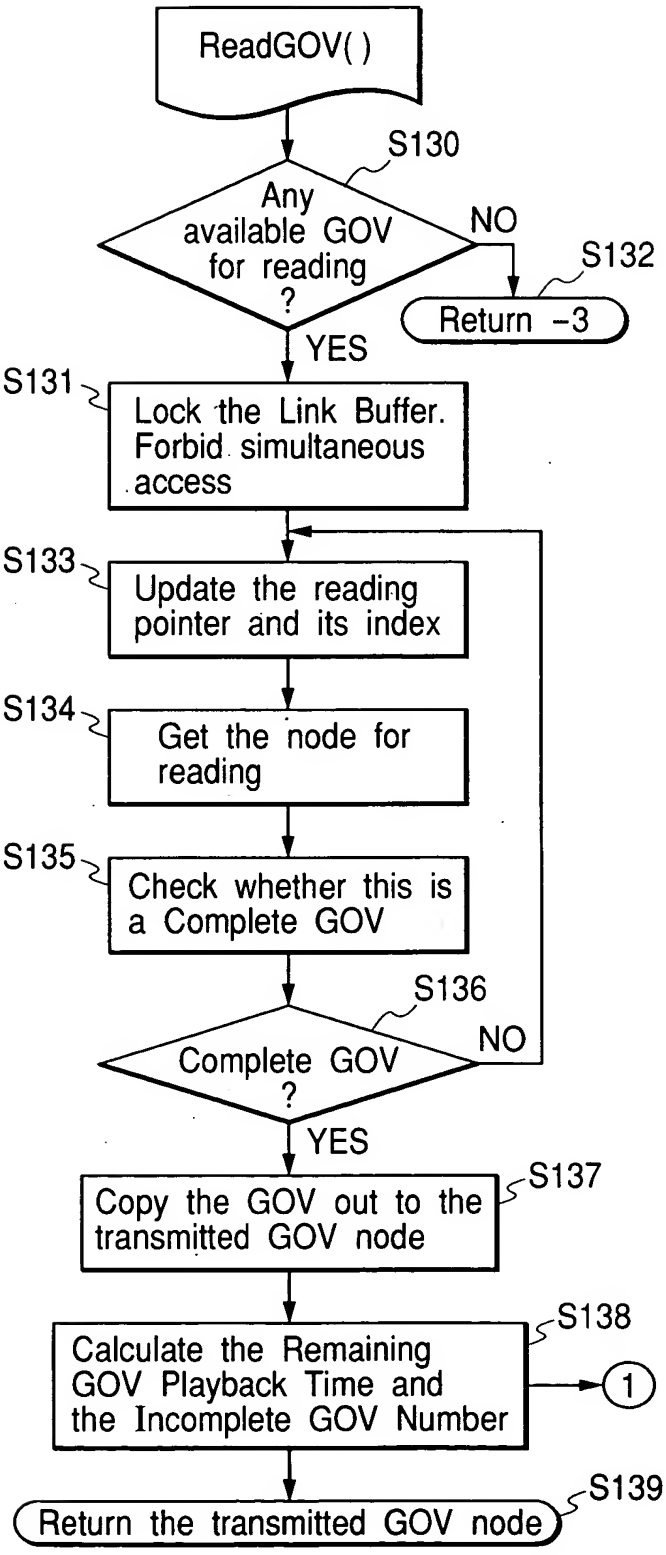

ReadGOV( )
S130
Any available GOV for reading ?
NO
S132
Return -3
YES
S131
Lock the Link Buffer. Forbid simultaneous access
S133
Update the reading pointer and its index
S134
Get the node for reading
S135
Check whether this is a Complete GOV
S136
Complete GOV ?
NO
YES
S137
Copy the GOV out to the transmitted GOV node
S138
Calculate the Remaining GOV Playback Time and the Incomplete GOV Number
1
S139
Return the transmitted GOV node

FIG. 19

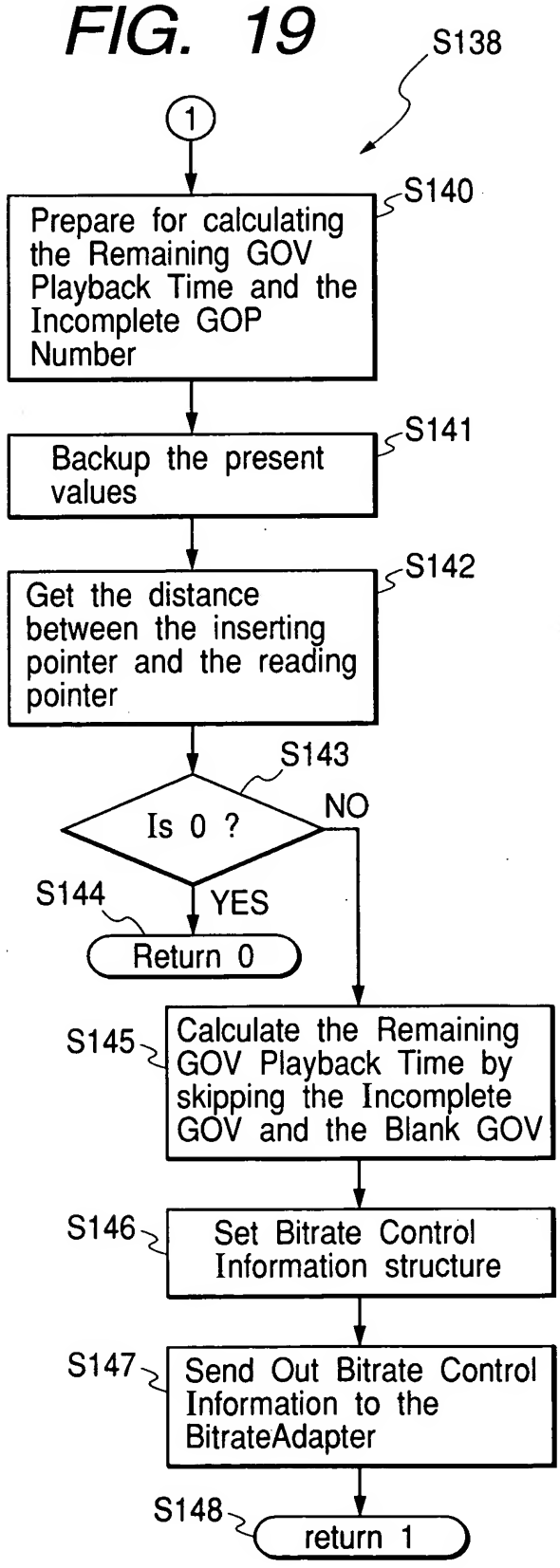

S138
1
S140
Prepare for calculating the Remaining GOV Playback Time and the Incomplete GOP Number
S141
Backup the present values
S142
Get the distance between the inserting pointer and the reading pointer
S143
Is 0 ?
NO
S144
YES
Return 0
S145
Calculate the Remaining GOV Playback Time by skipping the Incomplete GOV and the Blank GOV
S146
Set Bitrate Control Information structure
S147
Send Out Bitrate Control Information to the BitrateAdapter
S148
return 1

FIG. 20

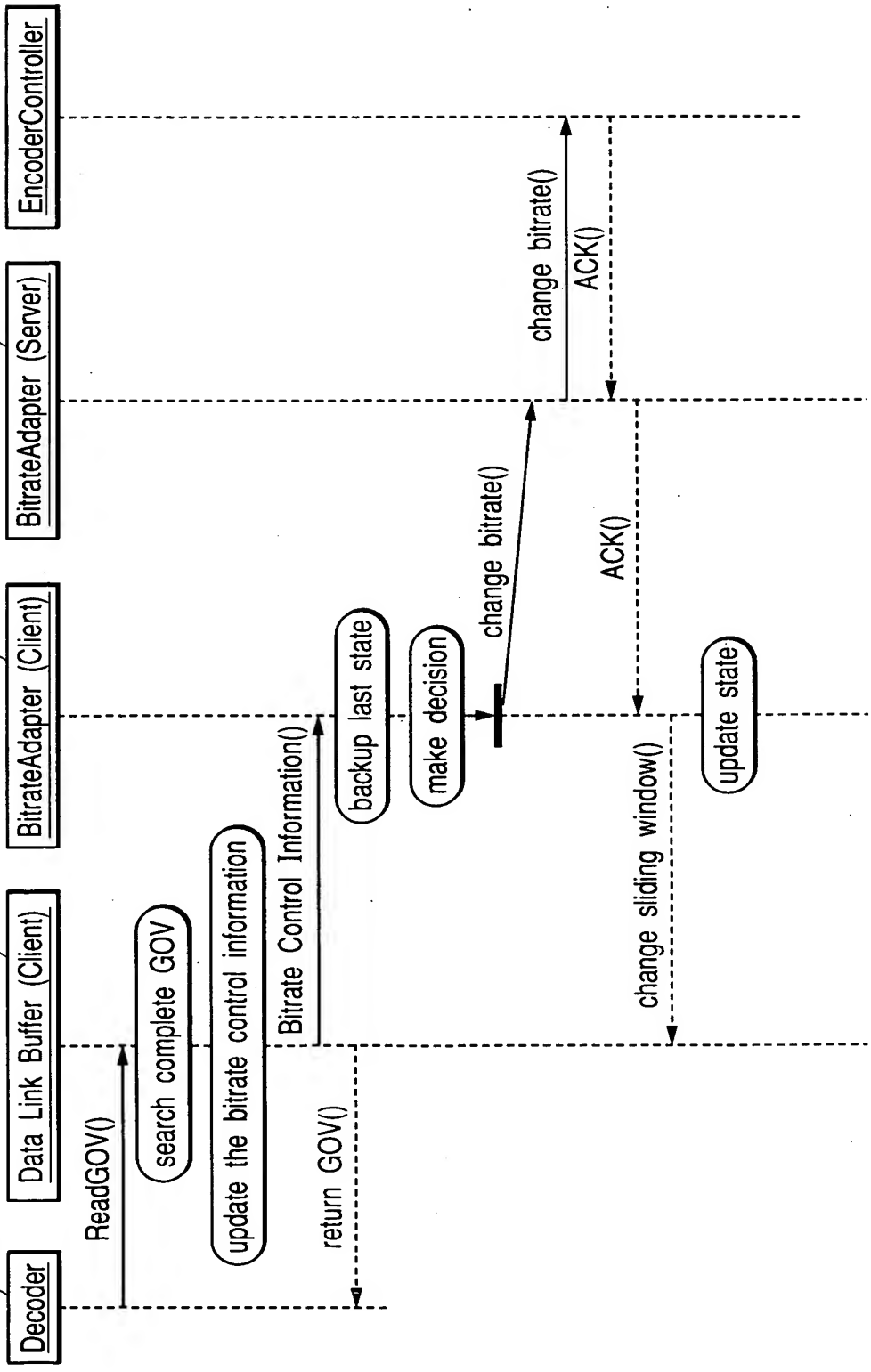

13
Decoder
28
Data Link Buffer (Client)
27
BitrateAdapter (Client)
23
BitrateAdapter (Server)
EncoderController
ReadGOV()
search complete GOV
update the bitrate control information
Bitrate Control Information()
return GOV()
backup last state
make decision
change bitrate()
change bitrate()
ACK()
ACK()
change sliding window()
update state

FIG. 21

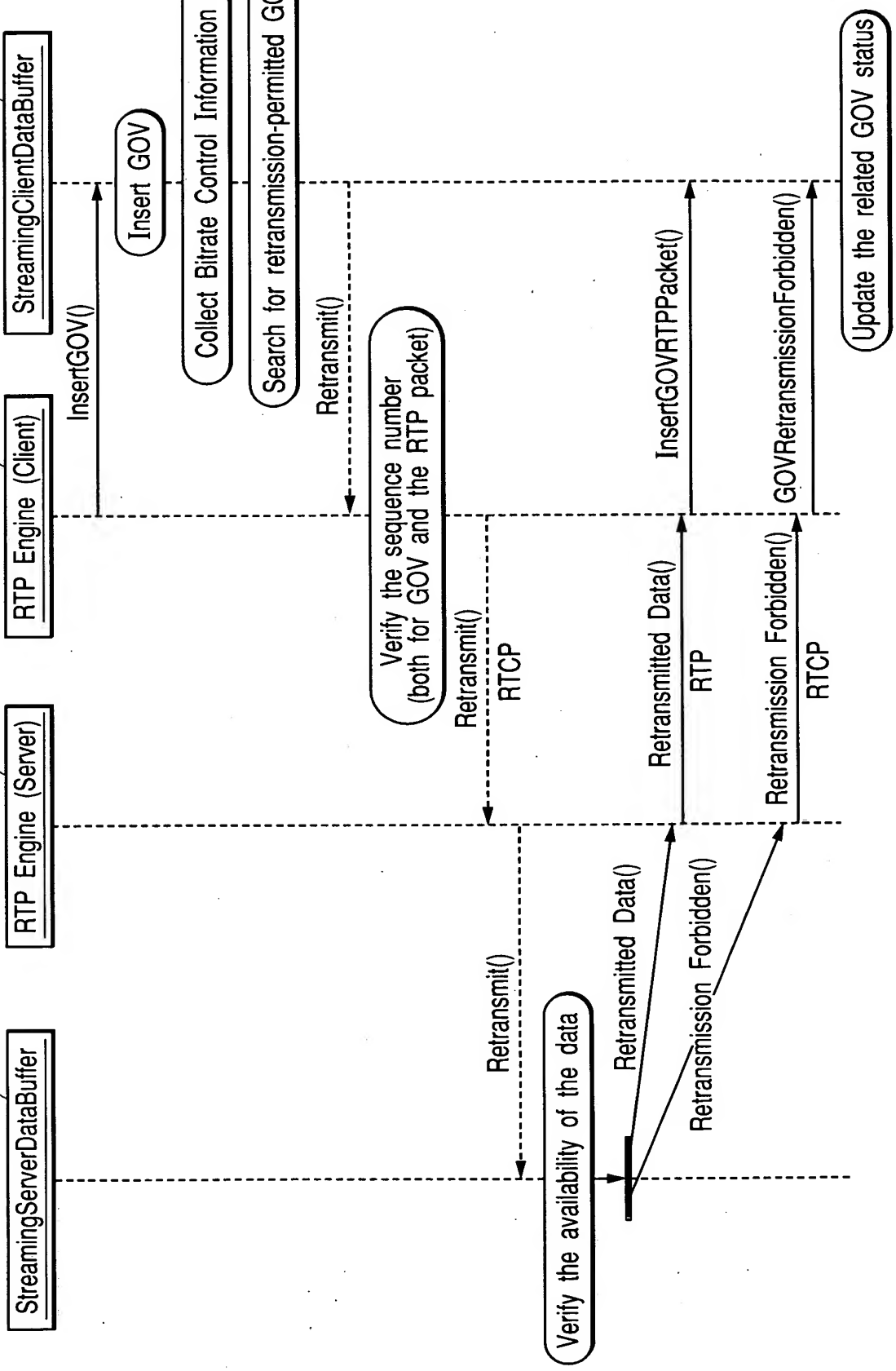

24
StreamingServerDataBuffer
22
RTP Engine (Server)
26
RTP Engine (Client)
28
StreamingClientDataBuffer
InsertGOV()
Insert GOV
Collect Bitrate Control Information
Search for retransmission-permitted GOV
Retransmit()
Verify the sequence number (both for GOV and the RTP packet)
Retransmit()
RTCP
InsertGOVRTPPacket()
Retransmitted Data()
RTP
GOVRetransmissionForbidden()
Retransmission Forbidden()
RTCP
Update the related GOV status
Retransmit()
Verify the availability of the data
Retransmitted Data()
Retransmission Forbidden()

FIG. 22

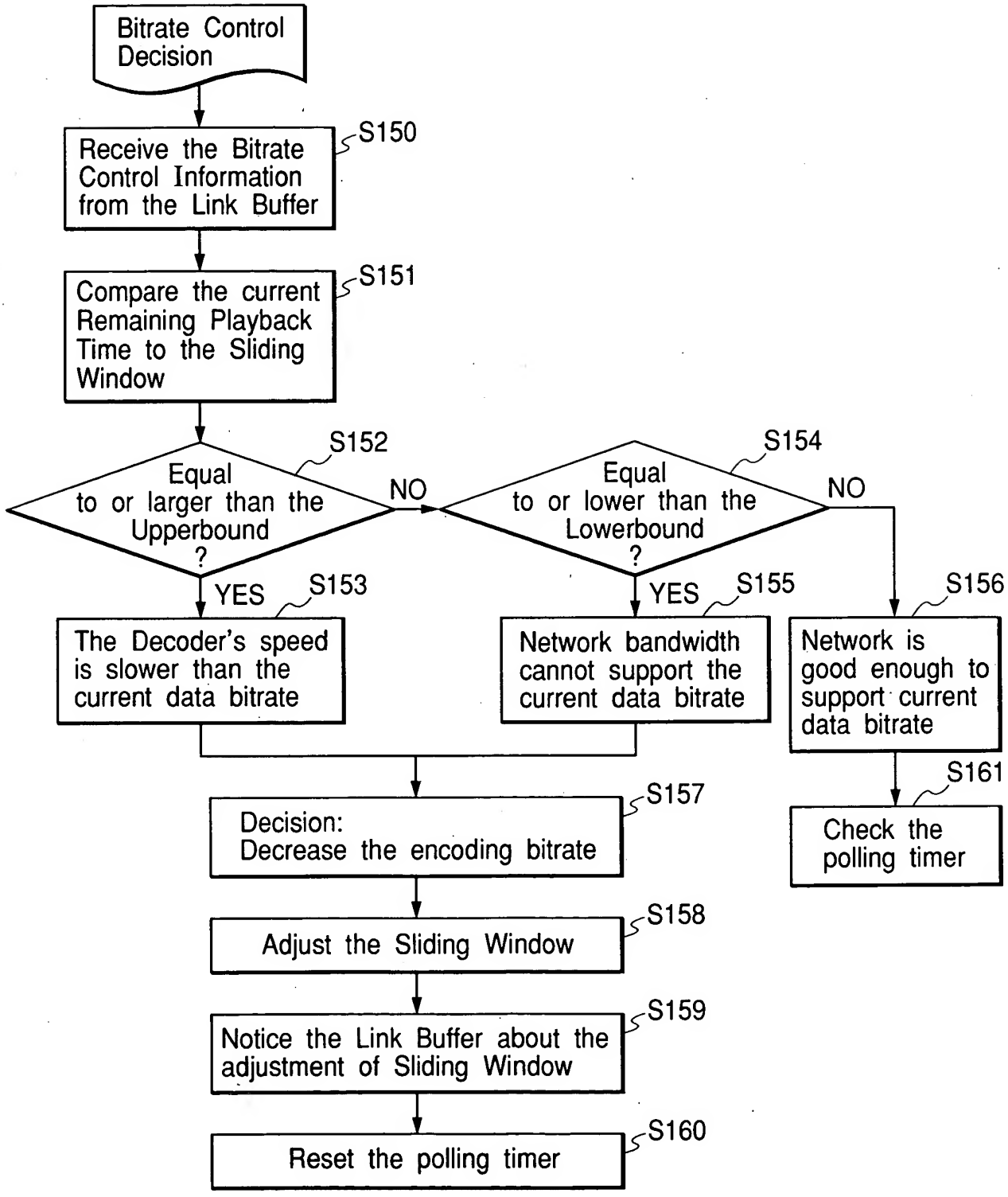

Bitrate Control Decision
Receive the Bitrate Control Information from the Link Buffer
S150
Compare the current Remaining Playback Time to the Sliding Window
S151
Equal to or larger than the Upperbound ?
S152
NO
YES
S153
The Decoder's speed is slower than the current data bitrate
Equal to or lower than the Lowerbound ?
S154
NO
YES
S155
Network bandwidth cannot support the current data bitrate
Network is good enough to support current data bitrate
S156
S161
Check the polling timer
Decision: Decrease the encoding bitrate
S157
Adjust the Sliding Window
S158
Notice the Link Buffer about the adjustment of Sliding Window
S159
Reset the polling timer
S160

FIG. 23

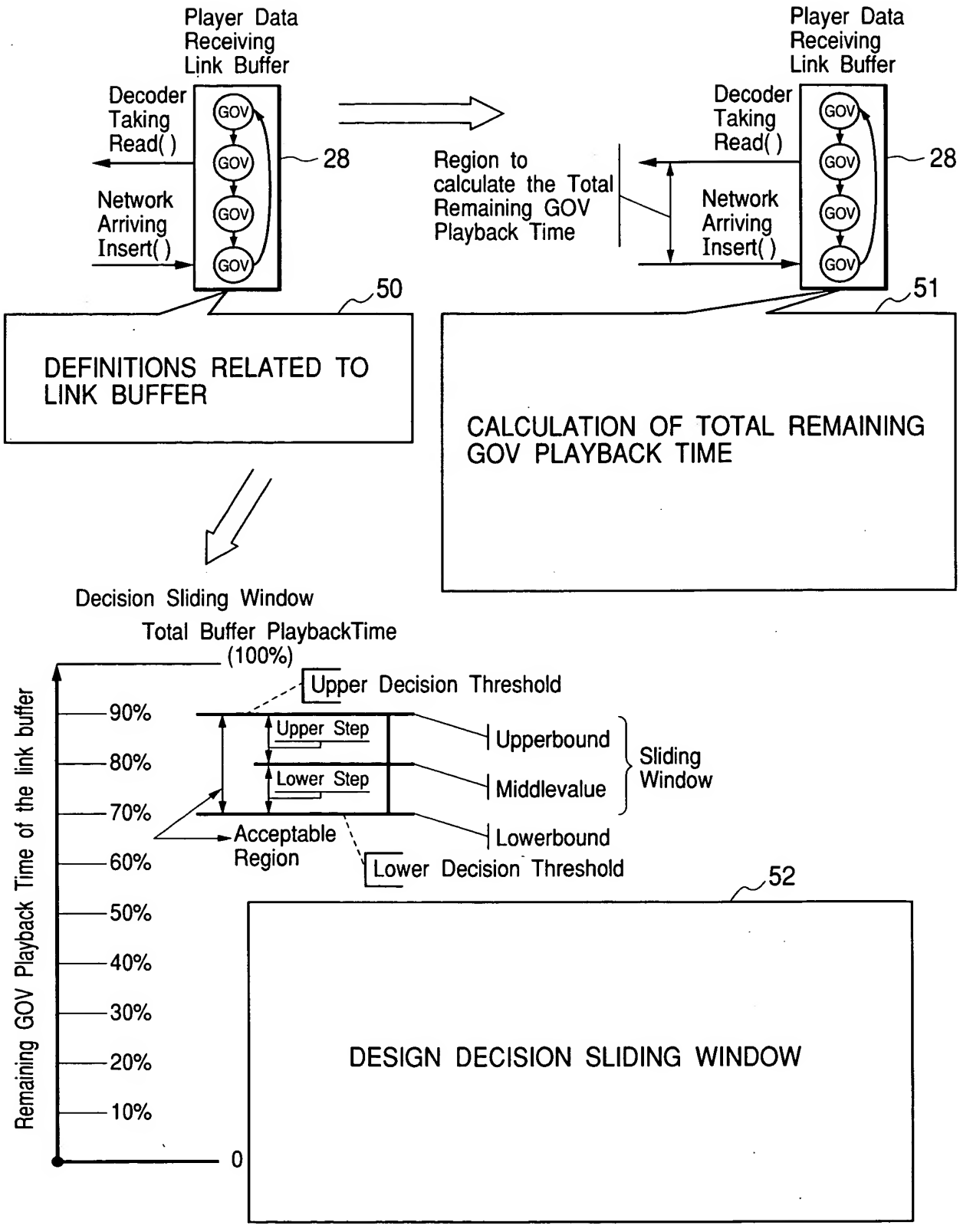

Player Data Receiving Link Buffer
Decoder Taking Read( )
Network Arriving Insert( )
GOV
28
50
DEFINITIONS RELATED TO LINK BUFFER
Region to calculate the Total Remaining GOV Playback Time
51
CALCULATION OF TOTAL REMAINING GOV PLAYBACK TIME
Decision Sliding Window
Total Buffer PlaybackTime
(100%)
Upper Decision Threshold
Upper Step
Lower Step
Upperbound
Middlevalue
Lowerbound
Sliding Window
Acceptable Region
Lower Decision Threshold
Remaining GOV Playback Time of the link buffer
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
52
DESIGN DECISION SLIDING WINDOW

FIG. 24

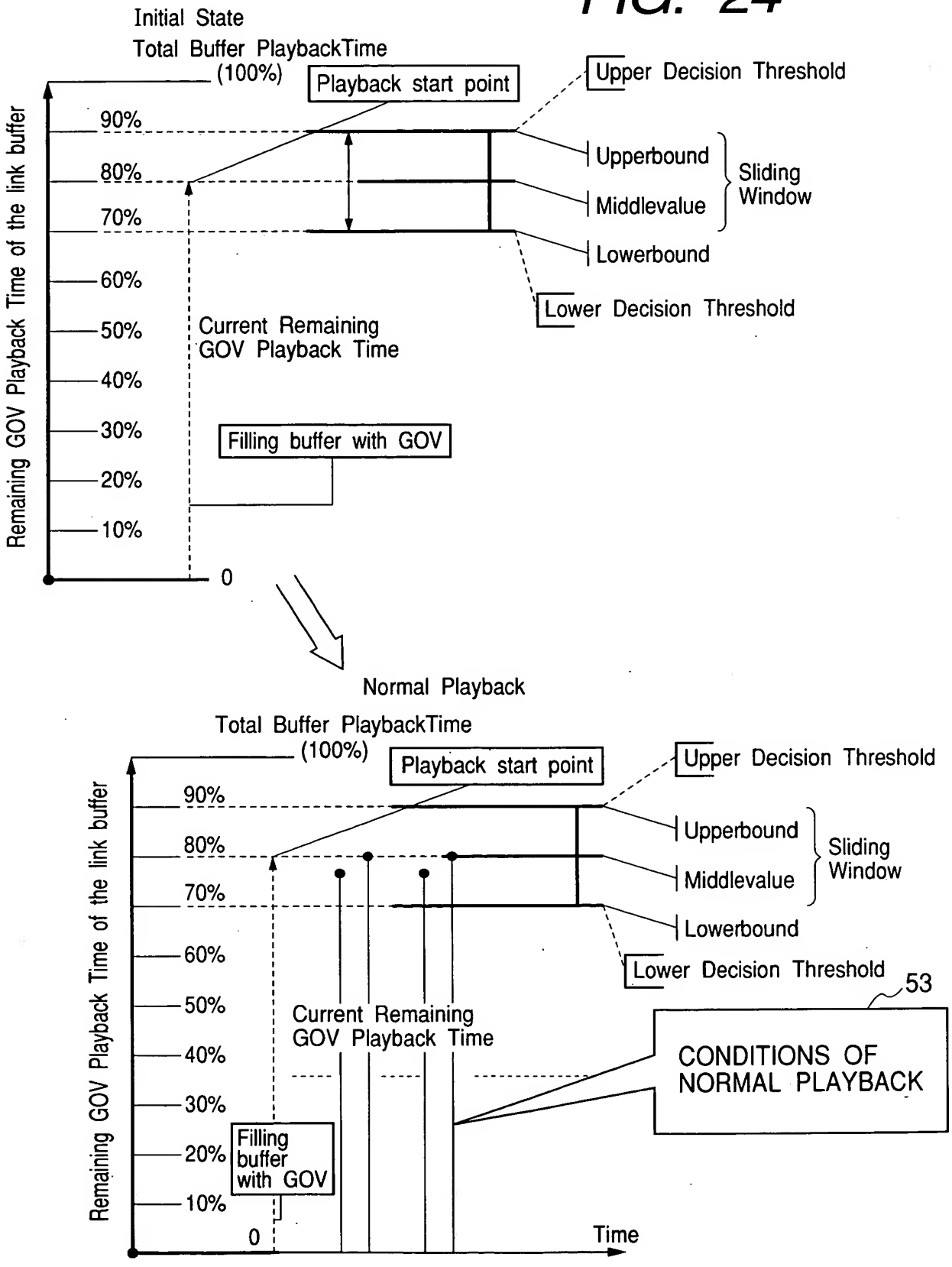

Initial State
Total Buffer PlaybackTime
(100%)
Playback start point
Upper Decision Threshold
90%
80%
70%
Upperbound
Middlevalue
Lowerbound
Sliding Window
60%
50%
40%
30%
20%
10%
0
Remaining GOV Playback Time of the link buffer
Current Remaining GOV Playback Time
Lower Decision Threshold
Filling buffer with GOV
Normal Playback
Total Buffer PlaybackTime
(100%)
Playback start point
Upper Decision Threshold
Upperbound
Middlevalue
Lowerbound
Sliding Window
Lower Decision Threshold
53
CONDITIONS OF NORMAL PLAYBACK
Current Remaining GOV Playback Time
Filling buffer with GOV
Time

FIG. 25

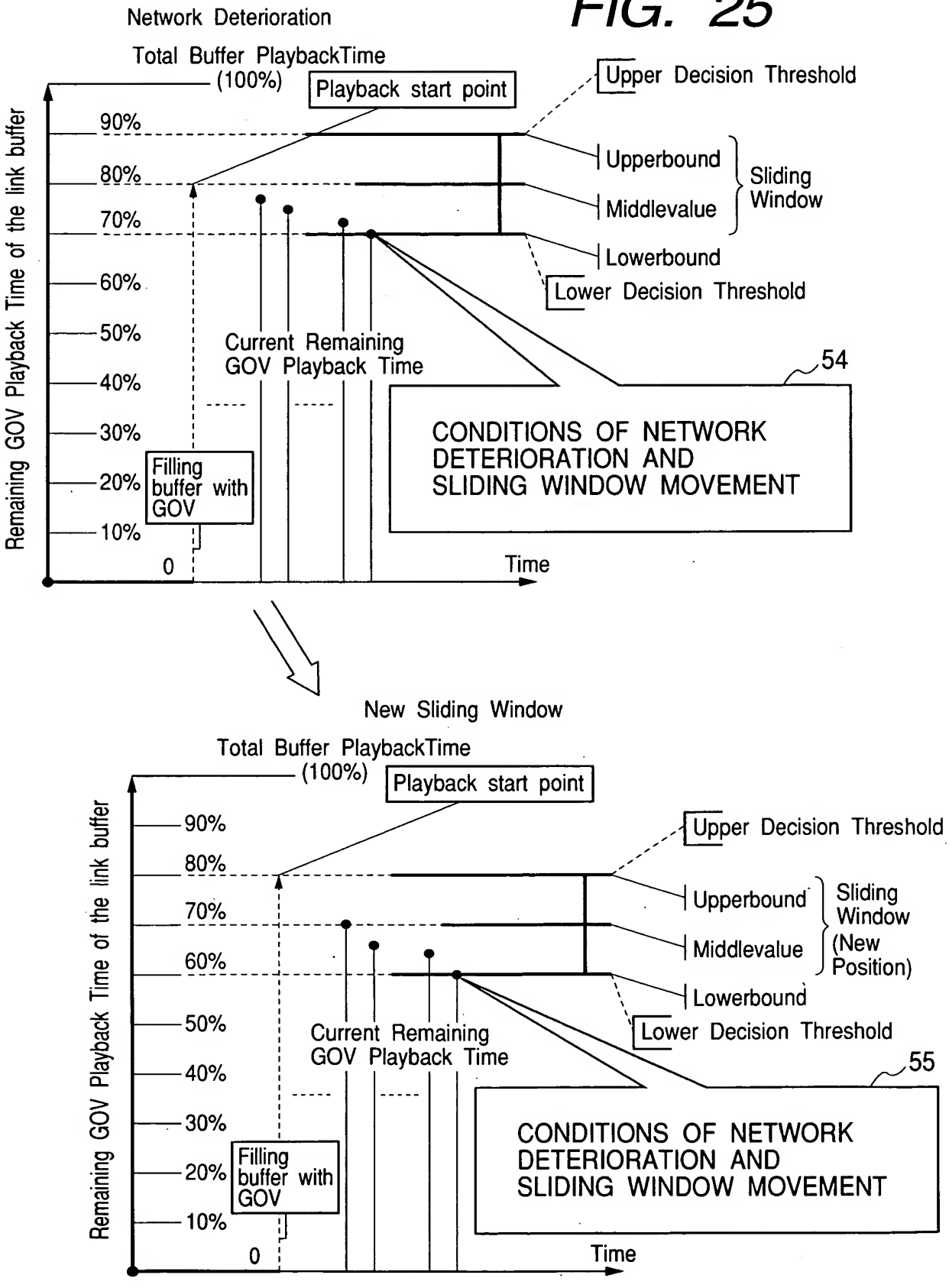

Network Deterioration
Total Buffer PlaybackTime
(100%)
Playback start point
Upper Decision Threshold
Upperbound
Middlevalue
Sliding Window
Lowerbound
Lower Decision Threshold
Remaining GOV Playback Time of the link buffer
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
Current Remaining GOV Playback Time
54
CONDITIONS OF NETWORK DETERIORATION AND SLIDING WINDOW MOVEMENT
Filling buffer with GOV
Time
New Sliding Window
Total Buffer PlaybackTime
(100%)
Playback start point
Upper Decision Threshold
Upperbound
Middlevalue
Sliding Window (New Position)
Lowerbound
Lower Decision Threshold
Remaining GOV Playback Time of the link buffer
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
Current Remaining GOV Playback Time
55
CONDITIONS OF NETWORK DETERIORATION AND SLIDING WINDOW MOVEMENT
Filling buffer with GOV
Time

FIG. 26

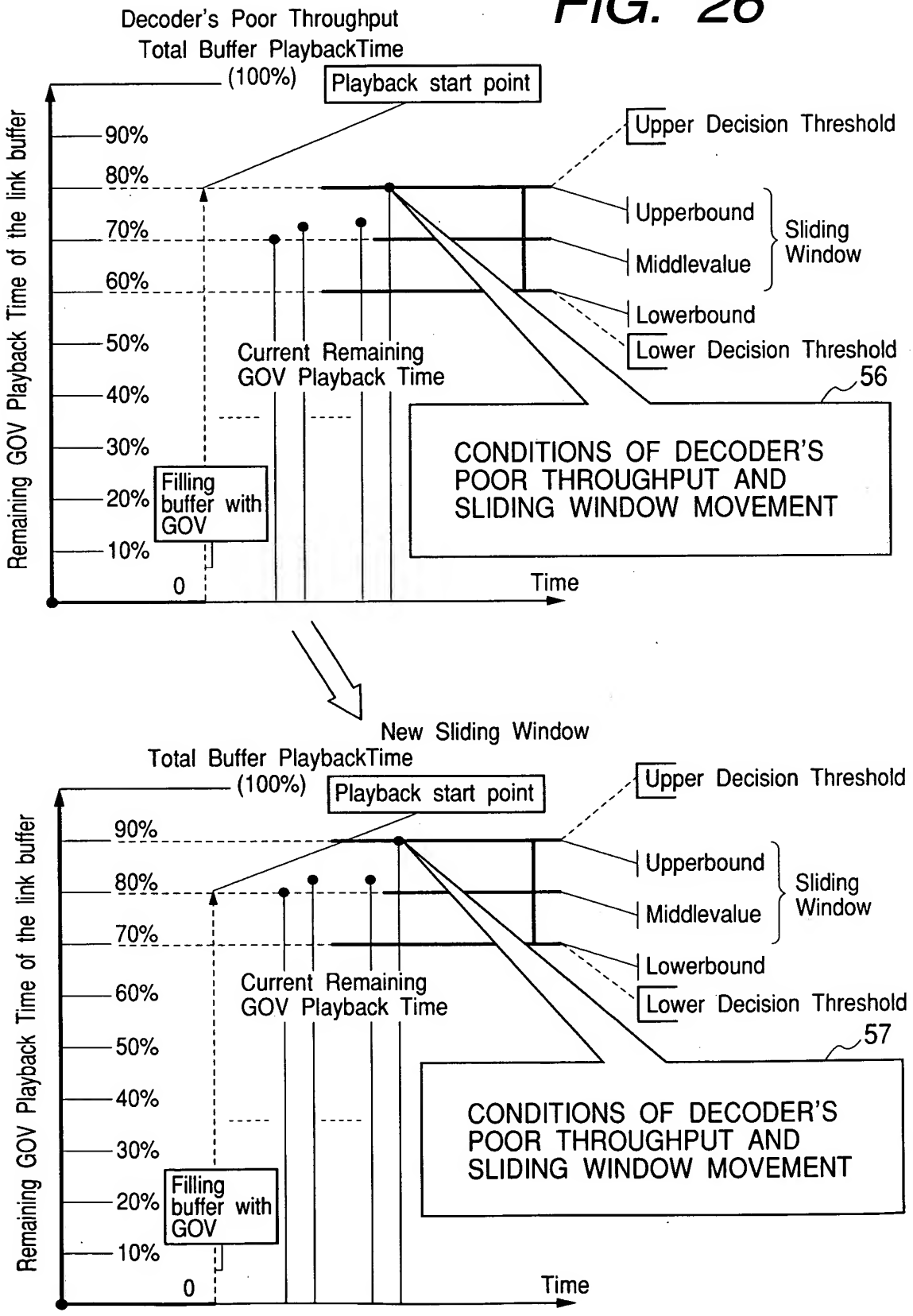

Decoder's Poor Throughput
Total Buffer PlaybackTime
(100%)
Playback start point
Upper Decision Threshold
Upperbound
Middlevalue
Sliding Window
Lowerbound
Lower Decision Threshold
56
Current Remaining GOV Playback Time
CONDITIONS OF DECODER'S POOR THROUGHPUT AND SLIDING WINDOW MOVEMENT
Remaining GOV Playback Time of the link buffer
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
Filling buffer with GOV
Time
New Sliding Window
Total Buffer PlaybackTime
(100%)
Playback start point
Upper Decision Threshold
Upperbound
Middlevalue
Sliding Window
Lowerbound
Lower Decision Threshold
57
Current Remaining GOV Playback Time
CONDITIONS OF DECODER'S POOR THROUGHPUT AND SLIDING WINDOW MOVEMENT
Remaining GOV Playback Time of the link buffer
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
Filling buffer with GOV
Time

FIG. 27

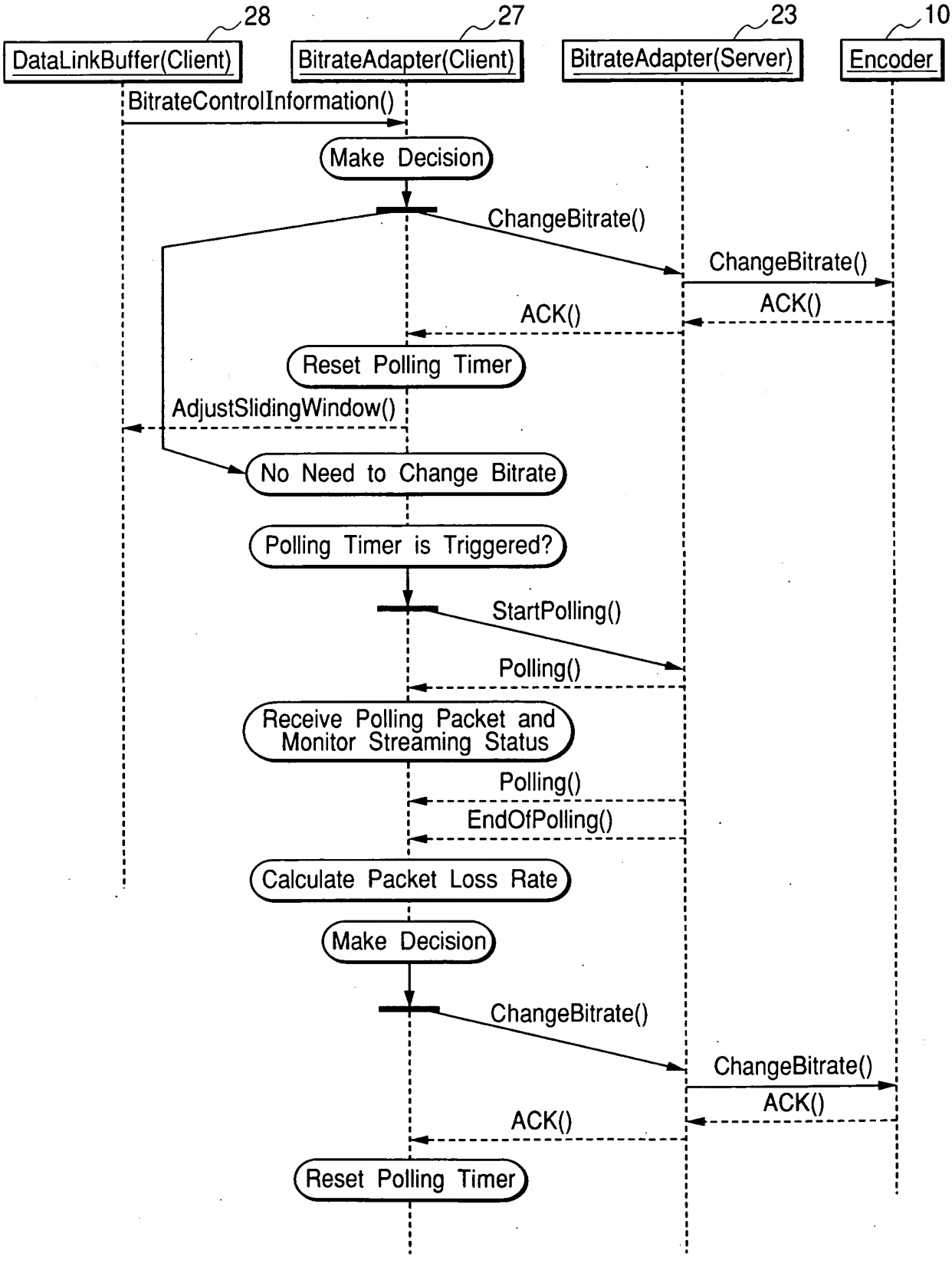
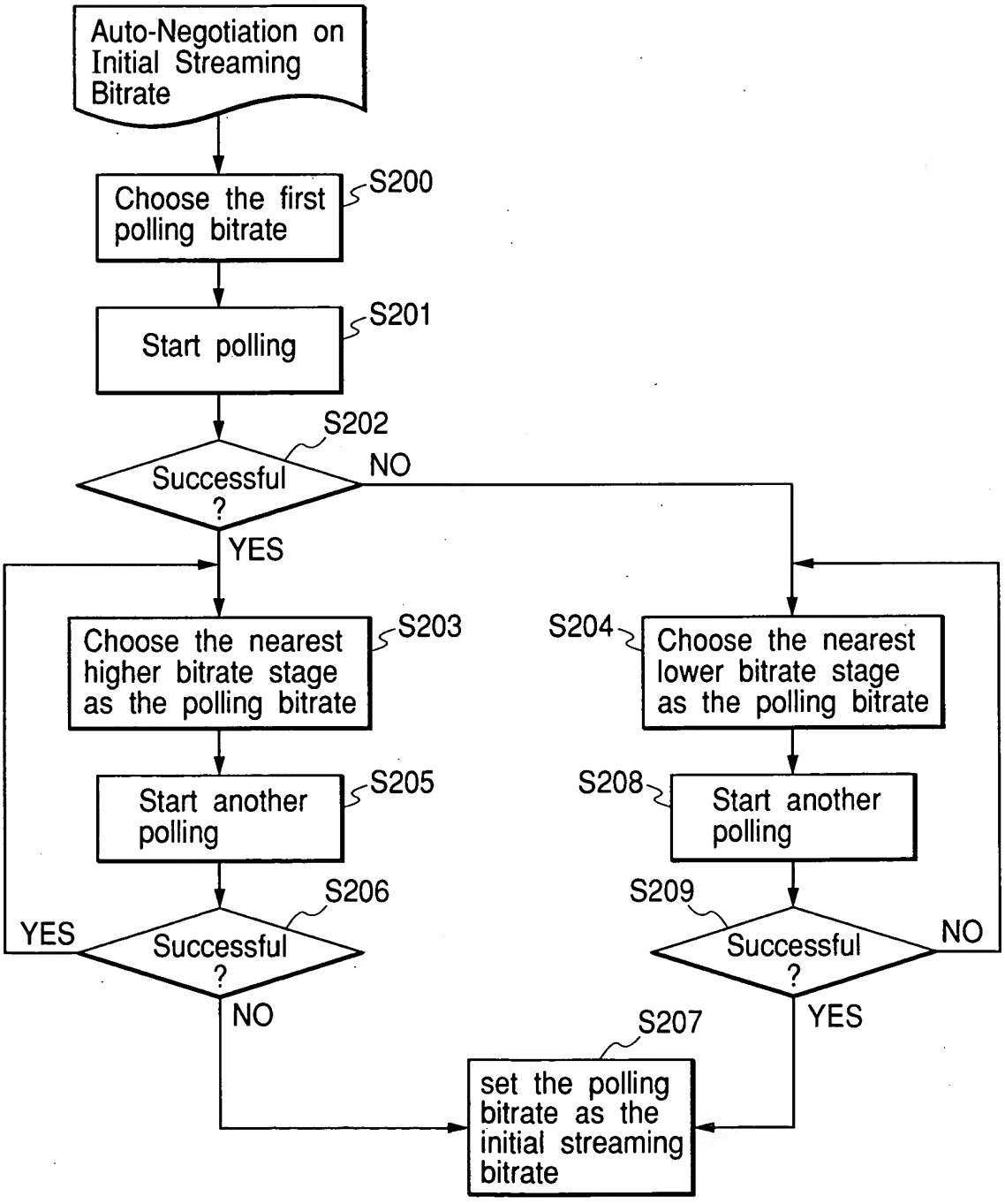

28
27
23
10
DataLinkBuffer(Client)
BitrateAdapter(Client)
BitrateAdapter(Server)
Encoder
BitrateControlInformation()
Make Decision
ChangeBitrate()
ChangeBitrate()
ACK()
ACK()
Reset Polling Timer
AdjustSlidingWindow()
No Need to Change Bitrate
Polling Timer is Triggered?
StartPolling()
Polling()
Receive Polling Packet and Monitor Streaming Status
Polling()
EndOfPolling()
Calculate Packet Loss Rate
Make Decision
ChangeBitrate()
ChangeBitrate()
ACK()
ACK()
Reset Polling Timer

FIG. 28


Auto-Negotiation on Initial Streaming Bitrate
Choose the first polling bitrate
S200
Start polling
S201
S202
Successful ?
NO
YES
Choose the nearest higher bitrate stage as the polling bitrate
S203
Start another polling
S205
S206
YES
Successful ?
NO
S204
Choose the nearest lower bitrate stage as the polling bitrate
S208
Start another polling
S209
Successful ?
NO
YES
S207
set the polling bitrate as the initial streaming bitrate